THE SELECTION AND USE OF PRECISE FREQUENCY AND TIME SYSTEMS

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Abstract

The ITU-R has authorized the creation of a handbook, "The Selection and Use of Precise Frequency and Time Systems." *This handbook is designed for use by the beginner in the field and for undeveloped countries that wish to establish a national laboratory or calibration laboratory. The lack of such a handbook is serious, so the ITU has decided to generate one. The editor, Richard L. Sydnor, and the assistant editor, David Allan, have selected authors for the various chapters from experts in the field and have correlated the work and generated the various drafts for the final version.*

The chapters and their authors are:

Preface and Forward		H. G. Kimball, ITU
Glossary		CCIR and ISO
Chapter 1	Introduction and Basic Concepts	Claude Audoin, Laboratoire de l'Horloge Atomique, France
Chapter 2A	Local Frequency and Time Sources	Andreas Bauch, Physikalishe-Technische Bundesanstalt, Germany
Chapter 2B	Steering References	Roger Beehler, NIST
Chapter 3	Characterization: Frequency Domain, Time Domain, Environment	Laurent-Guy Bernier, Observatoire de Neuchâtel, Switzerland
Chapter 4	Measurement Techniques (Metrology)	Fred Walls, NIST
Chapter 5	Characteristics of Various Frequency Standards	Richard Sydnor, Jet Propulsion Laboratory
Chapter 6	Time Scales	Claudine Thomas, BIPM, France
		Patrizia Tavella[1]
Chapter 7	Uses of Frequency Sources	Sigfrido Leschiutta[1,2]
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		Richard Sydnor, Jet Propulsion Laboratory
Chapter 8	Operational Experience, Problems, Pitfalls	Michel Granveaud, Observatoire de Paris, France
		Richard Sydnor, Jet Propulsion Laboratory
Chapter 9	Future Prospects	Leonard Cutler, Hewlett-Packard
Chapter 10	Conclusions	Donald Sullivan, NIST

*The work described in this paper was, in part, performed by the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration, and, in part, by the organizations listed with the various authors of the chapters.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **DEC 1996**	2. REPORT TYPE	3. DATES COVERED **00-00-1996 to 00-00-1996**
4. TITLE AND SUBTITLE **The Selection and Use of Precise Frequency and Time Systems**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **California Institute of Technology,Jet Propulsion Laboratory,4800 Oak Grove Drive,Pasadena,CA,91109-8099**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADA419480. 28th Annual Precise Time and Time Interval (PTTI) Applications and Planning Meeting, Reston, VA, 3-5 Dec 1996

14. ABSTRACT
see report

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**10**	

INTRODUCTION

The International Telecommunications Union – Radio (ITU-R) has decided that, in view of the fact that no handbook or general reference book covering the field of precise frequency standards exists, and that the need for such a book is critical for the developing countries and for students of the field, one should be generated. The authors were selected by the editors and have graciously donated their time and expertise to the completion of the book. Without their efforts and cooperation this work could not have been completed. Each chapter includes a list of references for those wishing to explore the topics of the chapter in detail. The book is now in the hands of the ITU-R for translation into several languages and will soon be available.

PREFACE, FORWARD, AND GLOSSARY

Mr. H.G. Kimball, the past chairman of the ITU-R, wrote the preface explaining the reason for publishing the book. The editors have written the forward giving a general description of the book and its contents, and where to find different topics. The glossary of terms used in the time and frequency field is based on the glossary that was originally generated by the CCIR (now the ITU-R) with additional definitions from ISO where there are differences or omissions.

CHAPTER DESCRIPTIONS

Chapter 1: Introduction and Basic Concepts

A historical background of the development of atomic frequency standards is given. The physics underlying commercially available atomic frequency standards are described and the means of applying them to frequency standards are outlined. The criteria which determine the performance of the various standards are discussed. In addition, quartz crystal oscillators are described because of their use in all the frequency standards. Every atomic frequency standard includes a quartz crystal oscillator and a certain amount of the performance of the frequency standard is due to the performance of the quartz crystal oscillator. Since this book is not designed to teach people how to design new frequency standards, but rather in how to use them, only commercially available precise frequency standards are covered, i.e., cesium beams, rubidium gas cells, hydrogen masers, and, of course, quartz oscillators.

Chapter 2A: Local Frequency and Time Sources

The actual implementation block diagrams and critical design parameters of the frequency standards based on the physics concepts of Chapter 1 are described and the use of the quartz crystal oscillator in each is outlined. Cesium, rubidium, hydrogen masers, and quartz crystal oscillators are covered in detail. Passive and active standards are covered.

Chapter 2B: Steering References

A complete listing of all the possible references that are available for syntonizing local frequency standards and for synchronizing local time standards to UTC coordinating with the SI second are given. Advantages and disadvantages of each are given, as well as the relative cost and complexity of operation of each of them.

Chapter 3: Characterization: Frequency Domain, Time Domain, Environment

Complete descriptions of the various measures of frequency and time stability, as used in the frequency and time field as well as those used in the commmunications field, written from a communications point of view, are presented. Cross-references are given to relate the communications point of view with the conventional frequency and time point of view. High-noise oscillators and low-noise oscillators are covered, as are the effects of frequency multiplication, and multiplicative and additive noise. This chapter covers true variance, $\sigma_y(\tau)$, Mod$\sigma_y(\tau)$, $S_\phi(f)$, $L(f)$, $S_x(f)$, TIE, structure functions, the Hadamard variance, and the high-pass variance.

Chapter 4: Measurement Technology (Metrology)

Measurement techniques for determining the characteristics of the frequency source are discussed in detail. Actual hardware examples of each technique are given, as well as things to be careful about. This is an updated and condensed version of some of the tutorials that have been given in the past.

Chapter 5: Characteristics of Various Frequency Sources

The actual performance in the time domain and frequency domain of available frequency sources are given. Systematic effects are included, giving the sensitivity of the different sources to environmental conditions and aging.

Chapter 6: Time Scales

The different time scales are defined and discussed, including TAI (International Atomic Time), UTC (Coordinated Universal Time), ET (Ephemeris Time), and UT# (the different Universal Times). A discussion of the means of generating time scales and examples of each are given, including the algorithms used by NIST and BIPM. The availability of documents for coordinating a local time scale with the BIPM are given, with examples of each.

Chapter 7: Uses of Frequency Sources

The many uses for frequency sources are described with specific examples described in detail.

Chapter 8: Operational Experience, Problems, Pitfalls

The real world operation of frequency sources with *caveats* about things that may degrade their performance. Reliability of the different sources is discussed and data are given for some standards.

Chapter 9: Future Prospects

Likely changes to expected in the future with the continual improvement of frequency sources and new technology are discussed.

Chapter 10: Conclusions

A wrap-up of the contents of the handbook and its use.

SUMMARY

The final draft was submitted to the ITU-R and is due to be published at the end of 1996.

APPENDIX: TABLE OF CONTENTS

Questions and Answers

JAMES CAMPARO (AEROSPACE CORP.): How are you people going to get copies of this to us?

RICHARD SYDNOR: Okay, I have a few copies here for people who are really interested. They are draft copies, there might be a few typos here and there and that sort of thing. If anyone wants to leave their name with me, I will contact you as soon as it's published and give you addresses and actual prices so that you can order copies.

JAMES CAMPARO: Would that be for both handbooks?

RICHARD SYDNOR: It's the same location for both handbooks, but I will give you information on this one. And then if you write to the address, they'll send you a catalog.

GERRIT de JONG (NMi VAN SWINDEN LAB, NETHERLANDS): The other handbook is not yet ready, so it's only this handbook.

JAMES CAMPARO: So you were referring to the one coming out in December?

GERRIT de JONG: No, only the manuscripts will be finished. So it will take maybe half a year or longer.

JOHN VIG (ARL): It sounds like there's a lot of good reference information in this book. Is there any chance that we could get at least some of it on the Web? Both Frequency Control and the PTTI now have a Web site.

RICHARD SYDNOR: Well, we have a copyright problem. It belongs to ITU. It would be a good idea. I can make a couple inquiries to find out. The price is quite reasonable, $30 or so for a technical book that's 200 and some odd pages full of information; and a lot of references if you wanted to delve deeper there into any of the topics.

JOHN VIG: I know that at least the contributions by government authors are not copyrighted.

RICHARD SYDNOR: Yes, but there are a lot of foreign authors, you know, some of the primary authors are from Europe. It's an international book, it's not a US book.